

16th APRIL, 1914

CITY OF LIVERPOOL.

(Beattie & Co.)
REPORT

OF THE

CITY BACTERIOLOGIST

ON THE

ELECTRICAL TREATMENT OF MILK,
WITH DETAILS OF EXPERIMENTAL
ENQUIRY AND APPARATUS.

LIVERPOOL :

C. TINLING AND Co., LTD., PRINTING CONTRACTORS, 53, VICTORIA STREET.

1914

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REPORT on the ELECTRICAL TREATMENT of MILK, with details of Experimental Enquiry and Apparatus.

In accordance with the resolution of the Health Committee, February 19th, 1914, I beg to submit a detailed Report on the apparatus used in the new process for the electrical treatment of milk, and to give the results obtained both with the experimental plant, which was erected in the Bacteriological Laboratory, and the larger plant erected at the Corporation Milk Dépôt at Earle Road.

Part of this information has already been given in a Report which I presented to the Health Committee on June 17th, 1913, but I think it very desirable that some of the matters stated in that Report should be repeated and emphasized, as the plant at Earle Road could not have been successfully built had it not been for the experience gained by the working of the experimental apparatus, which the Health Committee, at my suggestion, installed in the Bacteriological Laboratory.

Exhaustive researches as to the effect of electricity on bacteria in fluids were carried out by Cohn & Mendelsohn in 1879 (*“Über Einwirkung des elektrischen Stromes auf die Vermehrung im Bakterien.”* *Beiträge z. biologie der Pflanzen* 1879, 111, 141), and by Spilker & Gottstein in 1891 (*“Über die Vernichtung von Mikroorganismen durch die Induktionselektrizität,”* 1891). The latter workers actually investigated the sterilisation of milk. Work on the same lines has been carried out in France, America, Japan and in our own country with a greater or less degree of success. It may, therefore, seem unnecessary to refer to the earlier experiments carried on in Liverpool, but though no originality of conception is claimed for this work, yet I think it of very great interest and importance that a brief account of these earlier experiments should be recorded, for the construction of the present apparatus at Earle Road has been rendered possible not only by the successes, but by the failures in these research experiments.

For the details of this work I am indebted to Mr. F. C. Lewis, who has throughout conducted the great majority of the experiments.

Towards the end of the year 1911, several samples of milk, through which an electric current had been passed, were submitted for report as to their keeping qualities. The report was unfavourable. The apparatus used consisted of a vessel capable of holding several quarts of milk through which a direct current of electricity could be passed between two tinned-copper electrodes. This apparatus was slightly modified, but the results were again unsatisfactory. Some of the samples were partially sterilised, but this was due to the heating effect of the strong current which was employed.

The experimental work at this stage was transferred to the Thompson Yates Laboratories at the University with the consent of Professor Ernest Glynn, Acting Bacteriologist, and Mr. F. C. Lewis investigated the following problems:—

- (a) The possibility of utilising an electric current as a sterilising agent.
- (b) The scientific and other factors underlying a successful method, if one could be discovered.
- (c) The application of such experimental work to large scale practice.

It is not necessary to discuss all the difficulties that were encountered. Suffice it here to say that four main lines of investigation were pursued.

1. The effect of uni-directional currents on the milk. It was found that not only did sterilisation not occur under the conditions of the experiments, but that profound changes were produced in the constitution of the milk.

2. The effect of uni-directional and slowly alternating currents with the addition to the milk of minute quantities of salt with the object of producing electro-chemical sterilisation. By this method sterilisation could be brought about,

and inoculation of the treated milk shewed that the *B. tuberculosis* was destroyed. These inoculations were carried out by Professor Ernest Glynn. The milk, treated in this way, however, was spoiled from the consumer's point of view, again, on account of profound changes in the milk, and after many attempts to overcome the disadvantages this method was abandoned.

In connection with the experiments with uni-directional and slowly alternating currents with the addition of a small percentage of salt to the bacteria-containing fluid, it should be reported that a large measure of success attended this stage of the investigation. An apparatus was constructed, by means of which all kinds of bacteria could readily be killed. The apparatus consisted of a series of circular inter-communicating graphite-walled water-tight cells, through which the contaminated fluid passed. (Photo-diagram a, Figs. 2 and 3 and Photo 1.)

Inter-cell communication was made by an inlet at the bottom and an outlet at the top of each cell, the fluid thus making a tortuous course as shewn in Photo-diagram a, Fig. 2.

During the passage of the fluid to be treated, i.e., bacterial emulsion, through the cells, a current of electricity was continuously applied by means of brass terminals screwed on to each graphite plate. This apparatus was used in a variety of ways, for example, all the plates were coupled in series, or alternate plates were coupled in parallel with each other. In the first case, the current passed through the whole cell from end to end in one direction, whilst in the second case, the direction would be the same in alternate cells only, and consequently a bacillus as it passed from cell to cell would be influenced alternately by a current of opposite polarity. This was judged to be of importance because:—

- (a) by it, heating effects were largely avoided, and
- (b) a better mixing of the products of electrolysis occurred.

The principle upon which the apparatus works is that when an electric current of suitable strength is passed through even a weak solution of salt, part of the salt is decomposed, as also is part of the water. As a result chemical reactions occur and a body of high disinfecting value is produced. The body itself is unstable and rapidly disappears from its weak solution, but owing to its toxicity to bacteria rapidly destroys the latter.

Experiments with this type of apparatus shewed that bacteria of all kinds could be rapidly and effectively destroyed. Photographs 1 and 5. Tubercle bacilli in milk could be destroyed and the milk rendered free from other bacteria also. Owing, however, to chemical changes in the milk, the method was not available for general use.

3. The effect of static charges of electricity across a moving film of milk formed the basis of the next series of experiments but there was no appreciable effect produced on the bacteria (this need not be referred to further).

4. The effect of using a rapidly alternating current was then tried, and this was the foundation on which the system, which has now proved successful, was built. Even in the early stages of the work with this method it was shewn that the bacterial content of the milk could be reduced to a minimum and that the chemical constitution of the milk was apparently unimpaired.

Description of Experimental and Large-Scale Plant.

As the electric supply of the City is a continuous current, and as an alternating and a high tension current was required for these experiments, it was necessary in the electrical equipment to have an alternator driven by a direct current motor and a transformer, voltmeters, ammeters, etc.

The sterilising apparatus proper consisted of a long tube with three indentations (Photo.-diagram a, Fig. 1), which, after the insertion of copper or other electrodes, could be made water-tight. The distance between the electrodes and also the length of the

tube were definitely determined by experiments with an extensible (rubber) tube. The central electrode was connected with one pole of the transformer and the two outer ones in parallel with the other pole.

The whole apparatus was insulated by heavy glass supports. The milk was passed through the tube from a given height and at a given speed.

During the passage of the milk through the tube, the majority of the bacteria were destroyed. This apparatus was then improved chiefly in the design of the electrode entrances, which are now made separately according to the general plan, and dimensions shewn in Photo.-diagram b, Fig. 5.

The measurements of the apparatus are such as to allow free and unimpeded passage of the milk without the production of any eddies or pools, and at the same time to make certain that the electrodes adequately command every portion of milk passing through the tube. The upper and lower end of the central cylinder of the electrode chamber are made watertight with rubber stoppers and in these stoppers the copper electrodes are fixed. (Photo.-diagram b. Fig. 6.)

The improved design has been found to admit of general application to the process and is now incorporated in the large-scale plant. Instead of having a continuous tube, it was found advisable for many reasons to substitute three of these electrode chambers connected with one another by suitable lengths of glass tubing with rubber joints. (Photographs 2, 3 and 4.)

These electrode chambers and their connections will in the report be referred to as the *lethal-tube*.

At the inlet end of the lethal-tube there is a vessel containing the milk to be treated (Photographs 2 and 3) and this vessel is valved so that the supply can be regulated at will by the operator, whilst the outlet end is connected carefully, so as to avoid any infection, to a receiving vessel. The results obtained by means of

this apparatus were remarkably consistent and may be summarised as follows from about 140 separate daily tests. *Bacillus coli* and other bacteria of this group which are practically always present in milk and particularly abundant where manurial contamination is present were completely got rid of, and it follows that the bacillus of typhoid fever, if ever present, would also be destroyed as its general resistance is rather less than its group relation *bacillus coli*. The pus or abscess producing bacteria (*Staphylococci*, etc.) were also destroyed—though in some of the earlier experiments of this series a few bacteria of these types escaped. In regard to the bacillus of tuberculosis, experiments were made with naturally and artificially infected milk, and while in some cases the control animals (i.e., those inoculated with the milk before it was treated) died of septic poisoning, and the others, which lived long enough, developed definite tuberculosis, yet none of the animals inoculated with the same milk after treatment died, and when these were killed six weeks after the date of inoculation no trace of tuberculosis was found. These experiments proved that not only was the bacillus of tuberculosis destroyed, but that the bacteria which caused blood poisoning were also destroyed or so reduced in number as to render them harmless.

Other bacteria which have no definite relationship to disease were also in large measure destroyed but some of these, except in exceptional cases, were found in the milk after treatment. Thus it will be seen that the milk was only in rare instances absolutely sterile, but that it was free from dangerous or disease producing bacteria and from the ordinary milk-souring bacteria and that there was an enormous reduction in number of all other forms of bacterial life. The actual reduction was over 99 per cent. These remaining bacteria could be got rid of by more elaborate treatment but it was decided that as they were comparatively few in number, and so far as could be ascertained not concerned in the production of disease, the extra expense and the loss of time which this treatment would involve could not be justified in connection with the Corporation Milk Depot. Since the ordinary milk-souring bacteria were destroyed, it was only natural to find a great

improvement in the general keeping qualities of the milk. Thus, a tumbler of milk kept on the table in the Laboratory and merely covered to prevent dust contamination would be perfectly sweet and drinkable three days after it had been treated, whereas if it were kept absolutely free from air contamination, this period was increased, and samples have been found quite palatable after seven and eight days.

The chemical examination was made by Mr. Roberts, City Analyst, and his reports will be found attached.

These shew clearly that the chemical composition is unaltered (so far as chemical analysis can ascertain), they also give evidence of the non-increase of acidity (which, of course, is due to the destruction of acid forming bacteria), and the increased keeping power of the milk. Mr. Roberts also states that the lactalbumin, which is coagulated in ordinary sterilised milk, is not coagulated in the electrically treated milk. In addition the enzymes are not destroyed.

The various experiments proved the efficiency of the apparatus as a bacteria-destroying agent, and the next points to determine were whether the apparatus could be used for large quantities of milk, and whether its efficiency was maintained over longer periods than those on which it had been ordinarily employed. In the former experiments, about two litres of milk, were passed through the tubes in four minutes, equalling 30 litres (about $6\frac{3}{4}$ gallons) per hour. The apparatus was now given a non-stop run for from 1 to $1\frac{1}{2}$ hours, so that 9 gallons of milk were treated. The results obtained were quite as satisfactory as those obtained previously with the smaller quantities. At this stage a report was presented to the Health Committee (June 17th, 1913), in which it was stated that as the results of experiments with the experimental apparatus, it had been established that "the invariable result" was the "complete destruction of all colon bacilli and bacilli of similar nature, with an enormous reduction in the total number of bacteria of all kinds." Experiments with tuberculous milk were also reported, and these shewed that the bacillus of tuberculosis was destroyed.

"The results of chemical analysis are eminently satisfactory, and feeding experiments (on kittens), which have necessarily been limited in number and in time of treatment, have shewn that the nutritive value of the milk is not impaired."

These experiments were so satisfactory that steps were at once taken to have a larger plant installed at the Corporation Milk Depot, Earle Road.

The designing of the large scale-plant was determined by calculation based on the great mass of experimental data obtained from the previous smaller installation, and though there were no essential changes introduced into the design, various modifications in construction, &c., were found to be necessary. At the Earle Road Depot various structural alterations were necessary in order to install the new plant, and, at the outset, the matter was made additionally difficult by the lack of space, and it was found necessary to abandon parts of the original plan, which, as I have said, had been designed as the results of the experiments with the smaller plant.

In the upper floor at Earle Road there is a large tank capable of holding the full-day's supply of milk. This is connected with a smaller tank in which the milk can be maintained at a constant level, by a ball valve arrangement. This constant level tank is connected with the lethal-tube which is situated in the ground floor room (Photograph 4), and the flow through the lethal tube is maintained by gravity. From the lethal tube the milk is collected in receiving tanks, and from these it is conveyed into the bottling apparatus, which is situated in the basement. The milk is tipped into the supply tank by means of a combined churn-lifter and tipper, worked by hand and delivering the milk 15 feet from the street level.

The electrical apparatus consists of a direct current motor coupled to an alternating current generator, a high tension transformer, together with a current transformer, a pressure transformer, and the usual switch gear and regulating devices. The transformers

are kept in a fire-proof cupboard, the lethal tubes in a glass-fronted cupboard, and the switch board is so placed as to give the operator command over the whole installation. The motor and generator are in the basement, while the lethal tubes, &c., are on the ground floor.

Since the current used is a high tension one, considerable danger exists in its working unless adequate precautions are taken, and in the arrangement of the necessary safeguards, Mr. Breach and Mr. Robinson, of the Electrical Department, have given invaluable help.

Each electrode chamber is supported in detachable brass claws (Photograph 4) fitted on to a brass back-plate through which the high tension cable passes (Photo.-diagram b., Fig. 7 E) before it enters a vulcanite chamber (Photo.-diagram b., Fig. 7 C), in which it is connected to a spring terminating in a flat circular disc. (Photo.-diagram b, Fig. 7 D). The vulcanite chamber is covered by a circular vulcanite cap, and the whole chamber, with its spring content, forms a cap for the electrode chamber (Photo.-diagram b, Fig. 7). Placed in the electrode chamber is a nail-headed copper electrode (Photo.-diagram b, Figs. 5 and 6), the nail head impinging on the circular disc of the spring (Photo.-diagram b, Fig. 5), thus establishing good electrical contact.

The measurements of the lethal tube and electrode chamber are given in Photo.-diagram b.

These electrode chambers, supported and fitted as above described, are fastened to a polished slate slab, which forms the back of the glass-fronted cupboard already referred to. For purposes of safety in manipulation, the milk passes through aluminium tubes (Photograph 4) before and after passing through the lethal tube. These aluminium tubes have an earth connection, and so long as these remain intact there can be no leaking of the current through the milk to the supply or receiving tank. Other parts of the apparatus are also earthed.

In addition to these precautions, switches are so placed that if the cupboard doors are opened while the system is alive, the circuit is at once broken and the current cut off. Thus with ordinary care there is no danger to the operator.

Soon after the Earle Road apparatus was working, difficulties with "flashing" and charring of the milk, which had not occurred except in a minor degree in the experimental plant, were met with. This "flashing" was only noticed at the central electrode, and it was thought that it was due to a slowing down of the milk flow, after the apparatus had been working for some time. A specially-shaped electrode chamber which would overcome the results of any such slowing was constructed, but the difficulty was not got over. Ultimately, it was found that by using an electrode of higher conductivity, *e.g.*, copper (aluminium had been used at first on the large scale plant), the difficulty was overcome and a reversion was made to the former type of electrode chamber. Flashing gives a burnt taste to the milk, and as this might occur just at the end of a day's supply, and spoil the whole of the milk it was decided to introduce two small supplementary receiving tanks.

These two small covered tanks (Photo.-diagram b, Fig. 4) are fitted with gauge-glasses, their inlets are connected by an open channel, and their outlets with a covered channel commanding the main receiving tank. The milk from the lethal tube is first delivered into Tank F (Photo.-diagram b, Fig. 4), and when this is full, the delivery tube is put into the inlet of Tank F¹ (Photo. diagram b, Fig. 4). During this transference a small quantity of milk collects in the open channel between the two inlets, this milk can then be tested, and if satisfactory, the contents of Tank F can be discharged into the main receiving tank. Tank F is again filled, and Tank F¹ discharged, if its supply is satisfactory, and so on. In this way there is practically no risk of charred milk getting into the main supply, and, further, by the testing it would be possible to detect whether all the electrodes were working satisfactorily. There has been practically no recurrence of the flashing since the copper electrodes were introduced, but I consider these supplementary tanks of the greatest value.

Other Changes at the Earle Road Depot.

The quantity of diluted milk handled daily at Earle Road is from 100 to 125 gallons, and this amount has to be distributed in about 3,000 bottles. Experiments had shewn that the bottle-filling apparatus which was in use could still be employed, but that very special precautions were necessary to ensure that gross re-contamination of the milk did not take place. The filling apparatus was given a thorough trial, and it was found that re-contamination was taking place. This was due partly to the great difficulty in thoroughly cleaning the machine, and partly to the prolonged exposure to the air (in a room where bottle washing was going on and where dirty bottles were kept) during the filling, levelling and stoppering of the bottles. The bottles themselves were difficult to clean and the patent stoppers were undoubtedly a source of contamination. It was, therefore, decided to alter the shape of the bottle in order to facilitate cleaning and to substitute an ordinary cork stopper in place of the complicated spring and rubber stopper. It was anticipated that time would be saved and the chances of contamination greatly reduced. I may add that the cost of the bottles was reduced from about 16s. to about 11s. 6d. per gross. To further reduce opportunities for contamination, a much simplified filling apparatus was designed and introduced. This consists of a covered tank with entering tubes from the electrical apparatus, gauge glasses, and delivery taps, the latter being operated by a lever handle and their outlets covered by an inverted funnel.

The operator pushes the neck of the bottle close up to the funnel top, and fills the bottle up to the necessary graduation mark (the bottles have a scale marked on them), with practically no air contamination. The bottles can be filled very rapidly, and it has already been found that time is saved by this new method.

Bacteriological Examination of the Milk.

Bacteriological examination is made daily of the milk, both before and after treatment, and from time to time bottles are picked out at random from the stock which is being sent out and milk in these is also examined.

The following table gives the results of the examination on 15 successive days of the milk before and after treatment.

Date.	Control sample (untreated milk) 1 c.c.		Treated milk 1 c.c.	
	Bacteria present (grown on agar at 37° C.).	Bacteria grown on neutral red agar at 37° C. (<i>B. coli</i> , &c.)	Bacteria present (grown on agar at 37° C.).	Bacteria grown on neutral red agar at 37° C. (<i>B. coli</i> , &c.)
26/1/14	777,000	1,140	642	0
27/1/14	uncountable	180	327	0
28/1/14	125,400	1,320	53	0
29/1/14	158,400	29	189	0
30/1/14	568,000	656	316	0
31/1/14	567,600	912	168	0
2/2/14	80,000	600	100	0
3/2/14	97,500	798	16	0
4/2/14	126,500	105	22	0
6/2/14	35,400	436	0	0
8/2/14	96,400	25	87	0
10/2/14	152,460	17	130	0
12/2/14	112,200	676	75	0
13/2/14	19,840	96	348	0
14/2/14	950,000	432	49	0

The bacteria which grow on agar at 37° C. give a fairly accurate representation of the total number of bacteria present in any sample, while those which grow on *neutral red agar* are *B. coli*, and its allies mainly derived from manurial contamination, &c., and the main milk-souring organisms.

It will be seen then from this table that *B. coli* and the ordinary milk-souring organisms have been invariably absent from the treated milk, and that the average percentage reduction of total bacteria

over a period of 15 days was 99.93 %. Further, it will be seen that on only one occasion (February 6th) was the milk rendered quite sterile (as indicated by agar-culture at 37° C.), that the number of bacteria remaining varied from day to day, and that the number was always small. This is in strict accord with the statements I have made in the two official reports presented to the Health Committee on November 26th, 1912, and on June 17th, 1913, and also in accordance with the only scientific publication made on the subject—that in the *Journal of Pathology and Bacteriology* ("The utilisation of electricity in the continuous sterilisation of milk," by J. M. Beattie and F. C. Lewis, July, 1913), and which was reprinted and circulated by the Health Department. Further evidence of the bacterial destruction is given by the microscopical examination of the treated and untreated samples. The deposit obtained by centrifuging 100 c.c. of milk contains most of the bacteria. If this deposit is examined microscopically, there is a very striking difference between the treated and the untreated milk. In the former, very few bacteria are found in any sample, and even some of these bacteria shew partial destruction, while in the latter the bacteria are present in enormous numbers in some of the samples, and even in those which can be classed as "clean milk" the proportion of bacteria is much greater in the untreated samples.

Further evidence is given by inoculation experiments. The centrifuged deposit from the treated and the untreated samples has been injected into guinea-pigs.

From the 31st January, 1914, to the 27th February, 1914, 42 guinea-pigs have been inoculated with the centrifuged deposit, 21 with the deposit from the untreated (control milk) and 21 from the same samples of milk after electrical treatment.

From the untreated milk, five animals died within a week of the injection from blood poisoning, six were ill, but recovered, with ulceration and abscess formation at the site of inoculation, and two shewed very marked evidence of tuberculosis in the glands at the seat of inoculation.

From the treated milk, no animals died of blood poisoning, in only one was there a small abscess at the site of inoculation (and this was probably not connected with the milk, as the control animal from this milk shewed no abscess), and in none was there any evidence of tuberculosis.

I would call special attention to four of these guinea-pigs:—
a, a¹, b, b¹.

- a. Inoculated on the 31st January, 1914, with untreated milk.
- a¹. Inoculated on the 31st January, 1914, with electrically treated milk from the same sample as that with which "a" was inoculated.
- a. Developed well-marked tuberculosis.
- a¹. Shewed no evidence of tuberculosis on careful post-mortem examination.
- b. Inoculated on the 10th February, 1914, with untreated milk.
- b¹. Inoculated on the 10th February, 1914, with electrically treated milk from the same samples as that with which "b" was inoculated.
- b. Developed well-marked tuberculosis.
- b¹. Shewed no evidence of tuberculosis on careful post-mortem examination.

The bacteria which remain in the electrically treated milk have been isolated, and further experiments are being carried on to find out a means by which even these can be destroyed economically, but as I have already said, their presence does not in any way minimise the value of the process for the treatment of milk for infant feeding.

In order to shew the voltage amperage and temperature in the experiments, I attach a table giving the electrical readings at Earle Road for one day, as a type of the daily readings of the instruments.

Table Illustrating Electrical Readings of Test at
Earle Road, January 27th, 1914.

Time.	Volts.	Amperes.	Maximum Temperature.
a.m.			
8.47	3,950	2.3	61.5
9.0	3,950	3.25	60
9.10	3,900	2.2	60.5
10.0	3,900	2.22	63
10.15	3,975	2.15	62.5
10.30	4,050	2.2	63
10.40	4,050	2.15	63
11.0	4,150	2.1	63.5
11.20	4,200	2.02	62
11.35	4,200	2.05	64
noon	3,650	2.19	62

East unit quantity of milk is exposed to the temperature noted on the Table for such a brief period—some seconds—that heating effects can be neglected.

In conclusion, I would only add that difficulties of many kinds have been met with in the installation at Earle Road, difficulties which have resulted partly from the fact that a transference had to be made from the heat sterilising system to the electrical system without cutting off the milk supply even for a day.

These difficulties have necessitated delay in getting our full scheme into working order. It has to be recognised that the introduction of the large plant at Earle Road was an experiment, and that no one could say that it would prove as efficient as the small experimental plant had proved, and, therefore, I felt that it would be a mistaken policy to make any further alterations in the arrangements at the Depots than were essential to the working of the new

plant until a fair trial had been given as to whether or not it would be successful. For this reason I have urged that the Netherfield Road arrangement should not be interfered with at first, but that the work there should be gradually transferred to Earle Road.

This policy was also demanded, because the Staff at Earle Road had to be trained to new methods, and that only after gaining some experience would they be able to undertake the extra work. At present, the whole of the milk sent out from Earle Road is electrically treated, and also one-third of the Netherfield Road Supply.

**Summary of the Results obtained at the Earle Road Depot,
and which are Confirmatory of the Results obtained with
the Experimental Plant.**

1. That this electrical method of treating milk will destroy the disease producing bacteria which are found in it.

2. The main milk-souring bacteria are either completely destroyed or, if some members of this class are left, they may be neglected as far as the keeping power of the milk is concerned for ordinary household use.

3. The milk is not *sterilised* in the strictest sense of the word, but there is a reduction in the total number of bacteria by 99.93 % over a series of 15 daily examinations, and I would point out that even in heat sterilised milk and in Pasteurized milk, the whole of the bacteria are not destroyed, for the reason that some bacteria resist boiling temperature for some minutes, and that at temperatures below the boiling point, they may resist for prolonged periods. This difference is, no doubt, also exhibited towards electricity.

4. The milk will keep perfectly sweet for at least three or four days after treatment, and this period will cover distribution and use in all cases of household milk supplies. The keeping power is much prolonged if the milk is protected from after contamination.

5. The chemical constitution of the milk, as indicated by the reports of the City Analyst is, so far as can be ascertained by chemical analysis, unimpaired, and the taste is not in any way altered. The milk from this point of view may be described quite accurately as "Raw Milk."

6. As will be seen from the paragraphs of the Report relating to animal inoculation (p. 19), the milk is not only rendered non-pathogenic as regards ordinary bacteria, but in two cases in which the control supply was tuberculous, the electrically-treated milk was non-tuberculous, thus illustrating the destruction of the tubercle bacillus by the large scale plant—a fact already proved with the experimental plant.

7. The milk after treatment is, in my opinion, perfectly satisfactory as a food for infants.

Suggestions.

As the report shews, a very considerable advance has been made in rendering milk free from disease-producing bacteria, without, at the same time, impairing the chemical constitution of the milk, but absolute sterilisation has not been generally accomplished. It may be a matter for argument as to whether there is any advantage in obtaining absolute sterility. Personally, I am convinced that the bacteria which remain both from their number and from their nature, are not harmful, but I feel strongly that advantage should now be taken to encourage other workers to take up the subject. As I have indicated, destruction of bacteria by electricity has been engaging the attention of scientists throughout the world for many years.

I need only mention, in addition to the papers I have noted at the beginning of this report, the work done by Professor Thornton, and which was started in the University of Liverpool ("The Electrical Conductivity of Bacteria and the rate of sterilization of Bacteria by Electric Current," W. M. Thornton, D.Sc., *Proc. Roy. Soc.*, Vol. 85, 1912.)

It is, in my opinion, essential that this Report should be published in full, and circulated widely, so that the experiments made and the results obtained can be made known to men of science generally,

in order that they may not only know the stage to which the investigation has been carried in Liverpool, but that we also may have the benefit of their criticism.

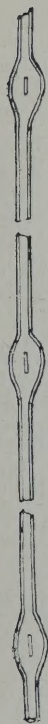
There are, naturally, in a prolonged research of this kind, many experimental details of purely scientific interest which it is not thought necessary to include in this Report, but which, I hope, will be communicated to a scientific journal as soon as the work is completed.

(Signed) J. M. BEATTIE,
City Bacteriologist.

11th March, 1914.

NOTE.—Since writing this Report, two more guinea-pigs inoculated with the untreated milk from Earle Road shewed definite tuberculosis, whereas the animals inoculated with the treated milk from the same samples were not tuberculous. (Dates of inoculation, 11th and 16th February, 1914.)—J. M. B.

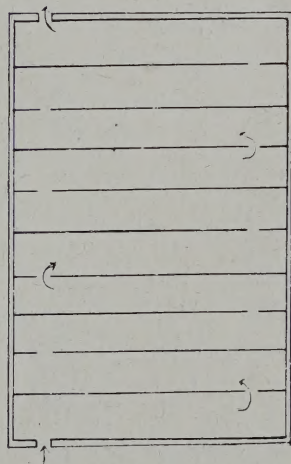
Fig 1



Original Bulb-Tube

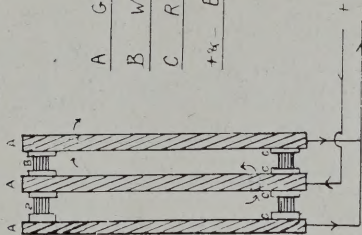
Electro-Chemical Cell.

Fig 2



General Scheme of Graphite Plates

Fig 3.



- A Graphite Plates.
- B Wooden Rings
- C Rubber Gaskets.
- + Electric Terminals

Details of Construction.

PHOTO-DIAGRAM (a).

Sketches relating to earlier experiments with unidirectional currents, or slowly alternating currents, combined with electro-chemical effects due to the electrical decomposition of salt (Figs. 2 and 3).

FIG. 1 shows the original "lethal-tube" with bulbs for the reception of electrodes.

Diagram of Auxiliary Tanks.

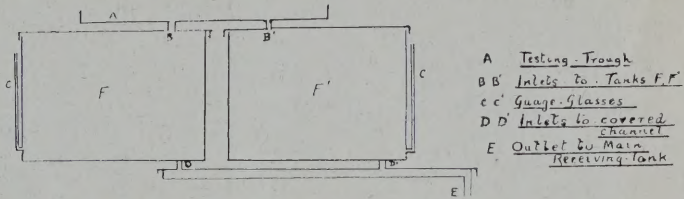


Diagram of Electrode Chamber

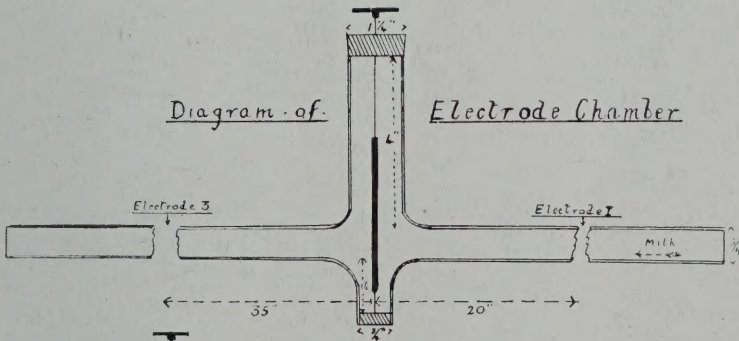


Diagram of Electrode

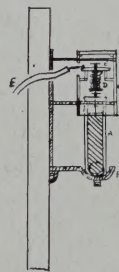
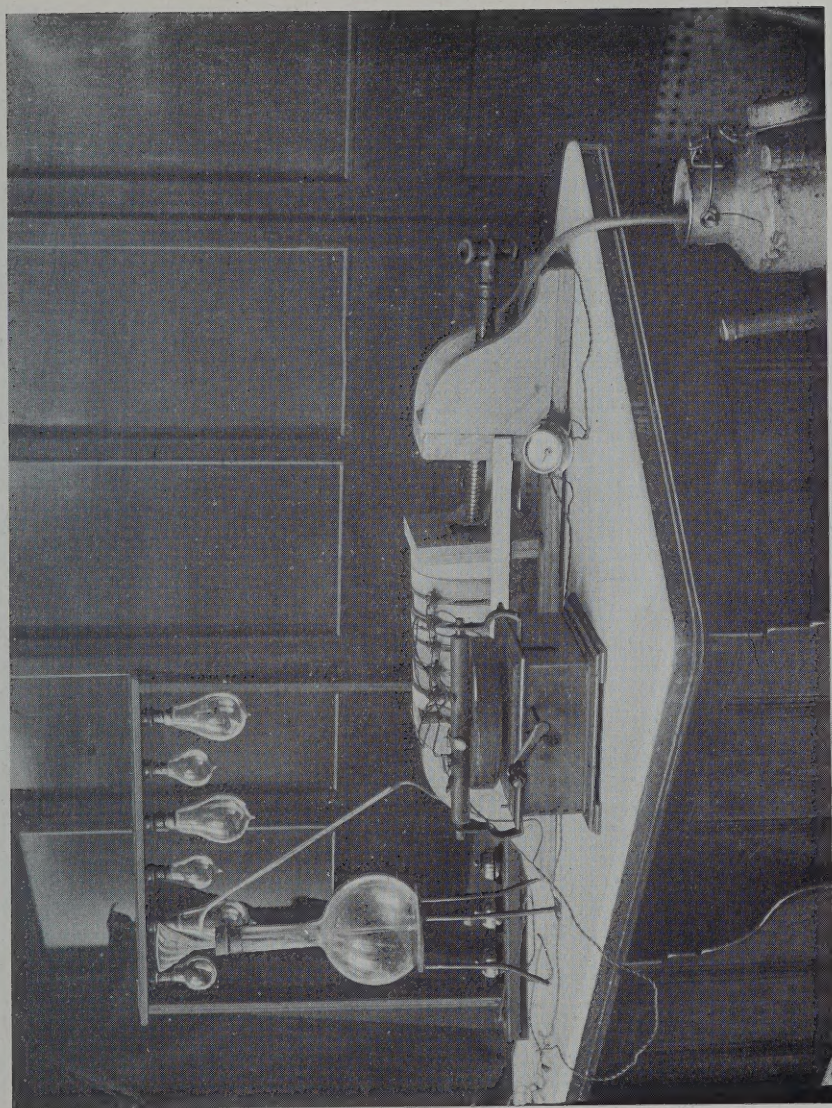


Diagram of Electrode Holder.
 A. Chamber. B. Claw
 C. Vulcanite Cap
 D. Spring. E. High Tension Cable.

PHOTO-DIAGRAM (b) ILLUSTRATING

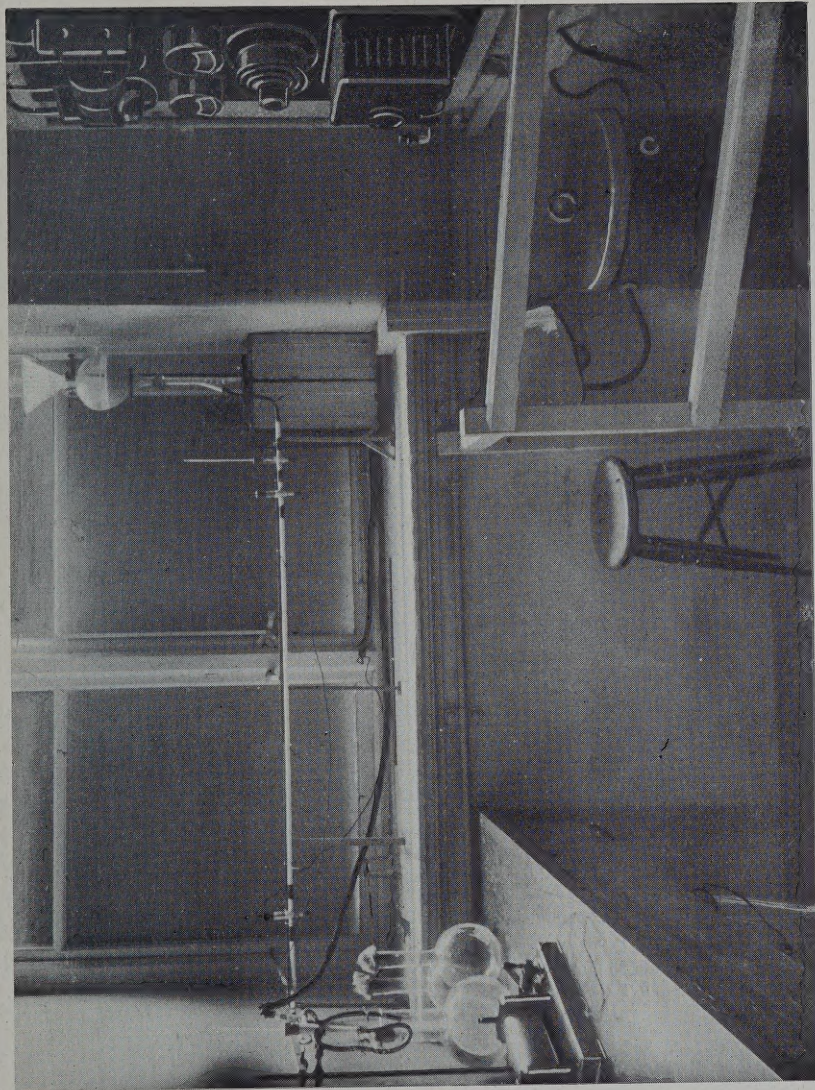
- FIG. 4.—Auxiliary receiving tanks for milk (used in connection with large-scale plant).
 FIG. 5.—Diagram of representative electrode chamber with contained electrode. This is drawn practically to scale, and measurements are inserted.
 FIG. 6.—Shows the general shape of a copper electrode.
 FIG. 7.—Shows diagrammatically the arrangements for ensuring safe electrical contact.



PHOTOGRAPH 1.

General photographic view of electro-chemical apparatus showing :—

- (a) Lamps from which current was taken.
- (b) Turn-table to produce slow alternations of current.
- (c) Circular graphite cells enclosed in wooden frame and made water-tight.

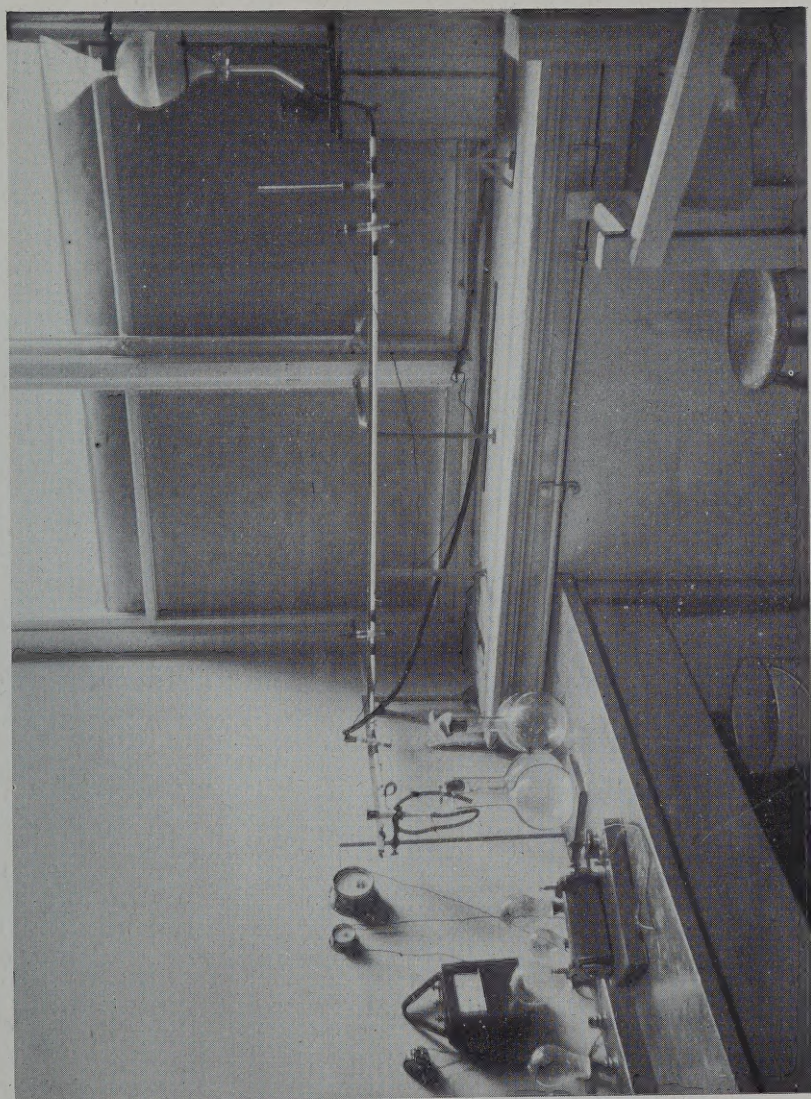


PHOTOGRAPH 2.

Photograph of experimental apparatus used in the bacteriological laboratories. On the extreme right of the photograph is the switch board from which the motor and dynamo in an adjoining room can be regulated. The current to and from the transformer (visible in lower right-hand corner) is also controlled at this board.

On the ledge in front of the window from right to left the following points can be observed : —

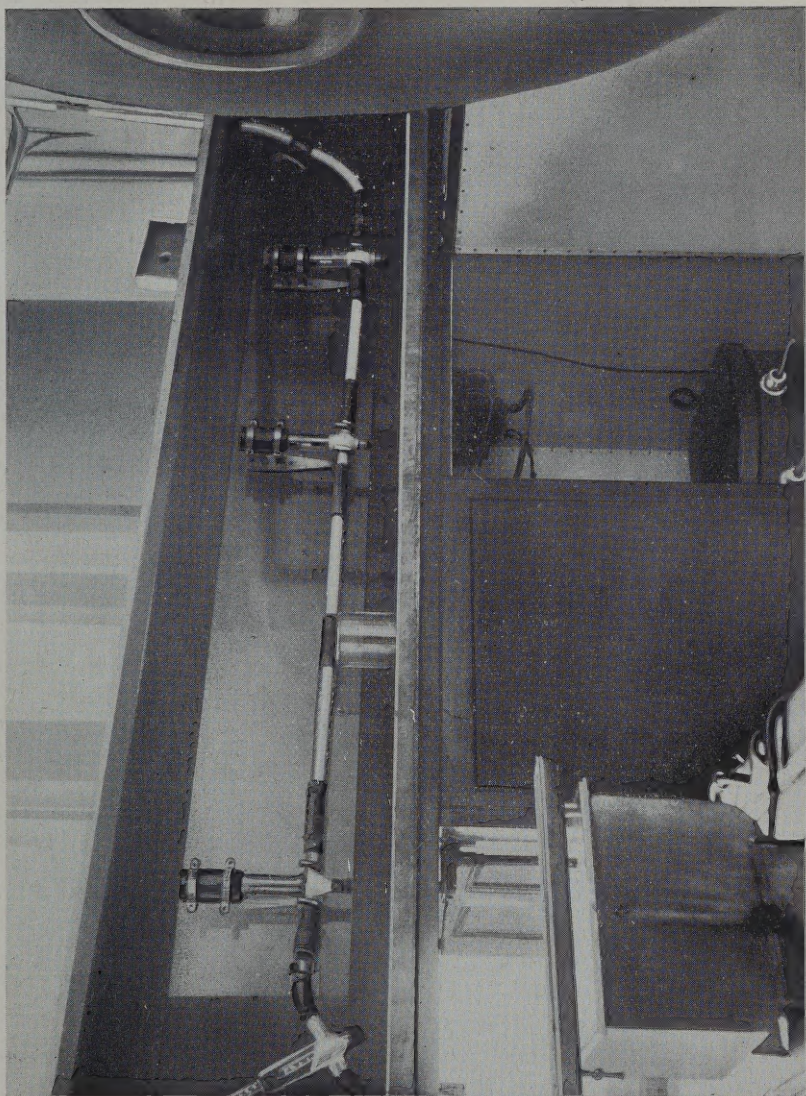
- (1) Bulb containing supply of milk.
- (2) Thermometer for indicating temperature of incoming milk.
- (3) Electrode and Electrode Chamber.
- (4) Length of "lethal-tube" leading to the central electrode. After this point a bend occurs in the tube, but the third electrode chamber can be seen on the left with thermometer and outlet for treated milk leading into a flask. The thick high-tension cables may also be seen, with thin cable connection to the electrodes.



PHOTOGRAPH 3.

This photograph is of the same apparatus as the preceding one, but taken at a different angle. The taps and regulators for controlling the flow of milk are more obvious. A little to the left of the centre, electrodes Nos. 2 and 3 are clearly shown. The disposition of the electric cables is clearer in this than in the other view of this apparatus.

The apparatus on the left is part of that which was used in other experiments



PHOTOGRAPH 4 OF THE APPARATUS AT EARLE ROAD.

The lethal tube, full of milk, can be seen in this photograph, together with three electrode chambers and electrode-brackets with curved supporting claws.

The inlet tube on the right and the outlet thermometer on the left are also observable. Terminals of the Transformer are shown in the asbestos-lined cupboard below, while in the lower left-hand corner is one of the auxiliary tanks, with the testing trough immediately above it (See Fig. 4).

Immediately to the right and left of the first and last electrodes, respectively, are shown the aluminium earthing tubes. Owing to the limited space at the disposal of the photographer, a more comprehensive view could not be obtained.



PHOTOGRAPH 5.

Photograph of plate cultures, illustrating result of treatment of bacterial emulsion with electro-chemical apparatus.

- (1) Before treatment.
- (2) Immediately after treatment.
- (3) Ten minutes after treatment.

[COPY.]

CITY ANALYST'S LABORATORY,

ASHTON STREET, LIVERPOOL,

16th April, 1913.

DR. E. W. HOPE,

MEDICAL OFFICER OF HEALTH,

LIVERPOOL.

Report on the analyses of Non-sterilised and Electrically Sterilised Milk received on the 9th April, 1913, from Professor J. M. Beattie, Liverpool University, per Wilfred Parkin.

The samples contained the parts as under:—

	No. 1 %	No. 2 %	No. 3 %	No. 4 %	No. 5 %	No. 6 %
Fat	4.10	4.00	3.75	4.10	3.30	4.00
Albuminoids	2.81	2.81	2.88	2.86	2.88	2.88
Milk Sugar	4.84	4.78	4.82	4.82	5.17	4.81
Mineral Matter	0.71	0.71	0.70	0.72	0.75	0.71
	12.45	12.30	12.15	12.50	12.10	12.40
Acidity calculated as lactic acid	0.55	0.57	0.63	0.58	0.23	0.66

As far as can be ascertained from a chemical analysis, no change takes place by the action of the electric current.

No. 5 is much lower in fat than the other samples, and this would indicate that the bulk had not been well mixed before the sample was taken. This sample remained uncurdled for one day longer than any of the others, and the acidity of the sample when received was much lower than in the other cases.

W. H. R.,

City Analyst.

[COPY.]

CITY ANALYST'S LABORATORY,

ASHTON STREET, LIVERPOOL,

30th April, 1913.

DR. E. W. HOPE,

MEDICAL OFFICER OF HEALTH,

LIVERPOOL.

Report on the analyses of Non-sterilised and Electrically Sterilised Milk received on April 19th and 23rd from Professor J. M. Beattie, Liverpool University.

The samples contained the parts as under:—

	No. 1 %	No. 2 %	No. 3 %	No. 4 %	No. 5 %	No. 6 %
Fat	3.35	3.35	3.30	3.30	4.20	3.65
Albuminoids	2.81	2.75	3.00	3.00	3.12	3.12
Milk Sugar	5.15	5.23	5.28	5.30	4.94	5.28
Mineral Matter	0.73	0.74	0.77	0.75	0.79	0.80
Acidity calculated as lactic acid	12.04	12.07	12.35	12.35	13.05	12.85
1st day	0.14	0.15	0.18	0.19	0.22	0.22
2nd day	0.15	0.24	—	—	—	—
3rd day	0.35	sour	—	sour	—	sour
4th day	sour	—	sour	—	sour	—

W. H. R.,

City Analyst.

Nos. 1, 3 and 5.—Electrically treated.

Nos. 2, 4 and 6.—Non-sterilised.

J. M. B.

